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AVIATION AND AERONAUTICAL ENGINEERING

VOL. VIII. NO. 12

Member of the Audit Bureau of Circulations

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AVIATION AND AERONAUTICAL ENGINEERING

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BUSINESS MANAGER

Vol. VIII July 15, 1920 No 12

LITTLE has been written of this phase of the study of lighter-than-air craft. In this issue the subject is considered quantitatively by a writer who finds some important uses for this force, which has hitherto been regarded as a disturbing factor in the operation of airships.

As in airplanes the stabilizer and elevator surfaces are not used to obtain lift directly but only as a means of controlling the angle of pitch which, as in the airplane again, is about 15 deg for the maximum lift.

In addition to the increased ceiling available with the aid of dynamic lift, a number of methods for using it to improve the maneuvering properties are discussed. The amount of ballast and gas lost may also be reduced. In this way, the efficiency of the ship is directly improved, as the reduction in ballast to be carried means a greater useful load which may be attained at the expense of a slightly increased fuel consumption.

As the size of the ship increases, the relative dynamic effect slowly diminishes, but this occurs at a lesser rate than the disposable lift.

Plywood Exposed to Oil

There has been hesitation shown in some quarters over the use of plywood in places where it is exposed to gasoline and oil A forty-five weeks' test at the Forest Products Laboratory, in which the plywood was kept immersed in gasoline, motor oil, and castor oil, showed that the glued joints were not greatly weakened. The shear strength did not fall below 125 lb per sq in., which is sufficient for ordinary service conditions. Although the wood absorbed from sixty to seventy per cent of its weight in gas and oil, no swelling was noticed. This is a valuable indication.

Unequal Loads on Wings

The effect of certain maneuvers or gusts is to impose greater loads on the wings on one side of an airplane than on the other Accelerometer tests show only the average of the wing loads, and there is some doubt as to what the difference is on right and left sides

A test conducted at McCook Field showed that the effect of unequal loading on the right and left wings of a biplane was such as to affect the overall factor of safety very little. Starting with the same load on both sides, the load on the left side was increased by one-half a factor of safety, while the right side was next made equal to and then a half factor heavier than that on the left. The process was then repeated with the left side so that the load on each side in turn was made equal to and then a half a factor of safety heavier than that on the other side. The tension in the lift wires was measured with a Larson tensiometer in order to determine how the stresses were being distributed.

With a factor of 7.5 on the left side and 7.0 on the right, the upper rear spar failed in bending about 20 inches outside of the center section strut station.

A similar set of wings had been previously tested and the difference in the factor of safety carried in the two tests agreed closely with the strengths of the material in the two sets of wings.

The conclusion reached is that a biplane wing structure can sustain unequal loads on either side without much reduction in factor of safety.

Comfort in the Cockpit

In spite of all attempts at standardization, the design of the cockpit still varies in every machine. It is interesting to see how careful some English designers are in attempting to secure the maximum possible comfort. In one case wet plaster of Paris casts were employed to obtain sound anatomical lines for the wicker seat. Instead of striking a happy mean for the length of a pilot's legs, the same designer obtained adjustment by a very simple means. The seat is supported on a plywood shelf, carried in its turn on spruce bearers which are attached by bolts and tubular rivets to vertical tubular fuselage struts. Four bolts furnished with fly nuts are attached to the seat and are free to slide in slots in the plywood shelf. These apparently minor details in design have real importance for machines which are to be in constant use

Small Commercial Airships

The small commercial airship which is illustrated in our present issue affords an interesting indication of the adaptability of lighter-than-air craft to the manifold needs of commercial aeronautics.

This craft was originally designed to serve for gun spotting in connection with fleet work, it being deemed that the greater mobility of an airship would enable it advantageously to replace the captive kite balloon. While this supposition has yet to be substantiated by exhaustive trials—which, we understand, are at present under way—the small vessel proved somewhat of a revelation in that it possessed, despite its small capacity and horsepower, good maneuverability, speed and endurance.

The adaptation of the type for air transport of a special nature, where not more than two persons have to be carried at a reasonable turn of speed and with the possibility of examining the underlying ground at leisure, was therefore a logical sequel to this development. This is a function which the airplane cannot fulfill to entire satisfaction because its high speed interferes with a detailed inspection of the ground; furthermore, the vision from the car of an airship is much less obstructed than that an observer can possibly obtain from the fuselage of an airplane.

The ship illustrated has been put into service to permit the supervision of extensive cotton plantations, where mounted observers were employed up to the present.

Dynamic Lift and Ceiling for Airships

By Alexander Klemin

Consulting Engineer, Aerial Mail Service, Consulting Aeronautical Engineer

The mathematical theory of the airship—whether equipped with ballonets or not—is practically complete as regards altitude maneuvers. But the dynamic effects on the airship both in maneuvering and in turn on ceiling have not been considered hitherto. At the suggestion of Comdr J C Hunsaker, a brief, non-mathematical exposition of this subject is undertaken in the present paper, with special reference to two well known examples of the rigid and non-rigid types

Some Useful Formulae

Lifting Power of Hydrogen at Standard Atmosphere
$F = 1.1\,V$
where F = lift in kg
V = volume of bag in cu. m

Standard Atmosphere and Air Density
Standard atmosphere is that found at sea level in latitude 45 deg and at a temperature of 0 deg Cent. under which conditions the pressure is 1 033 kg per sq. m where no water vapor is present, and is equivalent to the pressure of a column of mercury 760 mm in height. The weight of air under standard conditions is 1,293 kg per cu m.

Halley's Formula
$H = 18400 \times \log (P_o/P)$
where H is height in m.,
P_o is pressure of standard atmosphere
P is pressure at height under consideration and temperature variation is neglected

Density of Air at Altitude
$H = 18400 \log (D_o/D)$
where H = height in m
D_o = density at altitude considered where temperature variation is neglected.

Weight of Air Displaced by a Balloon at Any Altitude
$H = 18400 \log (W_o/W)$
where H = height in m,
W_o = weight of air displaced by balloon at sea level,
W = weight of air displaced by balloon at altitude considered and temperature variation is neglected

Law of Delestage for a Full Balloon
$H = 18400 \log [F \quad (F - f)]$
where H = altitude in meters of ascent due to rupture of equilibrium
F = total ascensional force at ground level
f = ballast thrown overboard or rupture of equilibrium and temperature effects are neglected

Loss of Gas During Ascent of a Full Balloon
Loss of lift in ascending to any altitude is equal to the buoyancy of the gas lost during the rise

Altitude at Which a Flabby Balloon Becomes Full
$H = 18400 \log (V/V')$
where V = volume of balloon and V' the volume of the gas in the balloon at the start

Calculations for Dynamic Lift on a Typical Dirigible of the Non-Rigid Type

The subject is best treated by concrete application to a definite case, and the non-rigid selected is the well-known British Admiralty S S Z, a small airship of the Blimp type, with a 100 hp engine and a pusher propeller. This is illustrated in Fig 1.

Model Dimensions of the S. S Z

MODEL 1/50 TH FULL SCALE

Total length	869 mm.
Maximum diameter	183 mm.
Fineness ratio	4 75
Volume of model	15046 cu. cm. or 0.532 cu. ft
Distance of center of volume from nose	379 mm.
Distance from the nose, measured parallel to the airship axis, of the hinge position of the fin flaps	714 mm.
Distance from the nose, measured parallel to the airship axis, of the point of intersection of the moments axis with the envelope (for all positions of pitch)	379 mm

DIMENSIONS OF FULL SIZED AIRSHIP

Nominal volume of full-sized airship	70,000 cu. ft.
Volume of airship calculated from drawing	66,500 cu ft
Distance from the nose, measured parallel to the axis, of the center of gravity of full sized airship	10 33 m.
Distance measured parallel to axis of the c.g of full sized airship	3.013 m.
Ballonets (2)	500 cu m total volume
Useful load	1766 lb. (approximately)
Maximum speed	77 km. per hr (approximately)
Cruising speed	55 km per hr (approximately)
Endurance at maximum speed	12 hr
Endurance at cruising speed	24 hr.
Ceiling	2400 m.
Engine, Rolls Royce Hawk	75 hp

When the non-rigid is used as a full balloon, it may be made to ascend by an initial rupture of equilibrium, produced by throwing so much ballast. For a ship such as the one described, it is interesting to investigate to what altitude it can rise when no ballast is thrown overboard initially.

When acting as a full balloon with an initial rupture of equilibrium, the airship rises with loss of gas, until the decrease in lifting power balances the initial rupture of equilibrium

When elevators are employed, a dynamic lift can be imparted to the ship which will enable it to rise to a certain height without initial throwing over of ballast.

At this position of equilibrium there will be a moment equilibrium with the couple due to buoyancy balanced by the

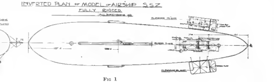


Fig 1

propeller thrust and the moment due to dynamic forces, as illustrated in Fig 2. Since the airship no longer rises, the inclination of the axis with the horizontal is also the angle of incidence or of pitch of the airship. The variation in engine power due to density variation may be neglected for the comparatively small change in altitude, as also the variation in dynamic lift due to change in density, since this is small compared to the change in buoyancy

As an illustrative example, suppose the airship has an angle of pitch of 8 deg in its final position of equilibrium, after rising from the ground with no initial rupture of equilibrium

Assuming that the wind tunnel drag values of the airship fully rigged require no appreciable correction for full scale effect, and that the best efficiency of the propeller is 75 per cent, the maximum speed with a 75 hp engine and a drag on the model of 0.1318 lb. at 40 ft./sec. and 8 deg incidence is 53 ft/sec or about 36 m p h. (which is somewhat lower than the actual test speed) The gross weight is 66,500 × 70/1000 = 4650 lb Since the useful load is 1760 lb. and the approximate position of useful load is 15 0 cm. from axis on the model or 7.5 m on the airship, the center of gravity is

$$\frac{3.013\,(4650 - 1760) + 1760 \times 7.5}{4650} = 4.71 \text{ m.}$$

The buoyancy couple is therefore

$4.71 \times 3.28 \times 4650 \times \sin 8 \text{ deg.} = 10{,}000$ ft. lb

Neglecting the moment of the offset propeller the corresponding pitching moment on the model must be at 40 ft./sec., where v is the speed of the dirigible $\dfrac{10{,}000}{50^3} \times \dfrac{40^2}{v^2} \times 12$ in. lb.

Assuming as a first approximation that the speed of 53 ft./sec. remains unchanged, moment is $\dfrac{10{,}000}{50^3} \times \dfrac{40^2}{53^2} \times 12 = .556$

The moment axis on the model test is sufficiently close to the center of gravity, so that no conversion of moments is necessary. The positive or stalling moment of the airship with zero angle of incidence is 0 66 The elevators would actually have to be set at a small positive angle, as this stalling couple would be slightly greater than the buoyancy diving couple.

The lift of the model under these conditions is .0179 lb. Since the airship is no longer climbing and the angle of incidence is small the entire lift is balanced by the change in buoyancy, and the amount of the lift is

$$\frac{.0179 \times 50^3 \times 53^2}{40^2} = 79.6 \text{ lb}$$

This is the equivalent of 1 7 per cent of the entire load, which is a somewhat low value for the initial rupture of equilibrium of a free balloon.

This corresponds to an altitude given by the law of delestage

$$18400 \log \frac{100}{100 - 1.7} \times 3.28 = 5000 \text{ ft.}$$

To Find Altitude of Maximum Dynamic Lift for the S. S. Z., When No Longer Climbing, at Altitudes Near the Ground

Just as for the airplane there is an altitude at which the machine has a maximum rate of climb, so for the airship there must be an altitude of maximum dynamic lift. We will investigate this altitude at ground level

The problem is slightly more complicated than that of the airplane, because the resistance coefficient of the airship varies

Fig 2.

TABLE I

TESTS OF AIRSHIP S S.Z (FULLY RIGGED)

Drag Forces on Model with the Body set at various Angles of Pitch and the Elevators at various Angles of Attack

Rudder at 0° Drag Forces (lb) Wind Speed 40 ft./sec.

Angle of Pitch	Setting of Elevators 0°	+12°	+24°	+36°	−12°	−24°	−36°
−6	0.1587	0.1051	0.1138	0.1150	0.1159	0.1812	0.1488
−4	0.1084	0.1085	0.1147	0.1153	0.1078	0.1231	0.1361
−2	0.1050	0.1091	0.1158	0.1221	0.1085	0.1233	0.1294
+2	0.1085	0.1124	0.1209	0.1254	0.1079	0.1141	0.1258
4	0.1080	0.1182	0.1271	0.1356	0.1108	0.1138	0.1234
6	0.1179	0.1278	0.1435	0.1535	0.1164	0.1139	0.1280
8	0.1318	0.1432	0.1596	0.1716	0.1251	0.1863	0.1293
10	0.1453	0.1625	0.1838	0.1988	0.1455	0.1458	0.1445
12	0.1697	0.1855	0.2081	0.2254	0.1889	0.1608	0.1628
14	0.1938	0.2188	0.2380	0.2601	0.1882	0.1888	0.1834
16	0.2263	0.2570	0.2761	0.2873	0.2098	0.2072	0.2062
18	0.2565	0.2880	0.3208	0.3408	0.2382	0.2365	0.2374
20	0.2929	0.3474	0.3674	0.3855	0.2801	0.2679	0.2679

TABLE II

TESTS OF AIRSHIP S.S.Z. (FULLY RIGGED)

Lift Forces on Model with the Body set at various Angles of Pitch and the Elevators at various Angles of Attack

Rudder at 0° Lift Forces (lb) Wind Speed 40 ft./sec.

Angle of Pitch	Setting of Elevators 0°	+12°	+24°	+36°	−12°	−24°	−36°
−6	−0.060	—	—	—	—	—	—
−4	−0.082	−0.310	+0.312	+0.014	−0.104	−0.138	−0.133
−2	−0.030	+0.010	0.049	0.081	−0.060	−0.157	−0.143
0	+0.005	0.030	0.065	0.095	−0.054	−0.100	−0.107
+2	0.049	0.093	0.138	0.140	+0.068	−0.037	−0.067
4	0.078	0.165	0.160	0.192	0.048	−0.010	−0.034
6	0.129	0.188	0.230	0.262	0.084	+0.039	+0.025
8	0.170	0.244	0.277	0.267	0.130	0.078	0.072
10	0.208	0.298	0.330	0.352	0.181	0.124	0.127
11	0.266	0.325	0.366	0.411	0.225	0.167	0.158
19	0.283	0.351	0.398	0.451	0.253	0.208	0.189
12	0.326	0.384	0.435	0.488	0.278	0.262	0.258
14	0.361	0.420	0.462	0.481	0.306	0.257	0.298
16	0.390	0.451	0.487	0.537	0.330	0.299	0.361
18	0.431	0.477	0.525	0.568	0.359	0.312	0.348
18	0.479	0.541	0.582	0.614	0.410	0.353	0.402
20	0.515	0.595	0.665	0.681	0	0.397	0.430

TABLE III.
Tests of Airship S.S.Z. (Fully Rigged)

Pitching Moments on Model with the Body set at various Angles of Pitch and the Elevators set at various Angles of Attack. Rudder at 0° Pitching Moment (lb. in.) Wind Speed 40 ft./sec.

Angle of Pitch	Setting of Elevators 0°	+12°	+24°	+36°	−12°	−24°	−36°
−4	—	−1.22	−1 40	−1 46	−0.03	+0 00	+0.06
−2	−0 40	−0 94	−1.21	—	+0 16	0 80	1 06
0	−0 11	−0 60	−0 87	−1 00	0 44	0 92	1.07
+2	+0 20	−0 61	−0 77	−0 90	—	1.10	1.28
4	0 37	−0 33	−0 90	−0.08	0 05	1 35	1.40
6	0 63	—	—	—	—	—	—
8	0 60	−0 18	−0 61	−0 78	1 21	1 05	1.70
10	0 67	—	—	−0 92	—	1 90	1 72
12	0 54	−0.21	−0 82	−1.22	1 21	1 51	1 68
14	0 43	−0 27	−0 86	−1 29	1.23	—	1.23
16	0 40	−0.47	−1 00	−1 34	1 17	1 08	1 06
18	0 34	−0.55	−1.10	−1 44	—	—	1 09
20	0 34	−0 03	−1.21	−1.40	1 17	1 40	1 34

TABLE IV

Angle of Pitch	Buoyancy Couple (ft./lb.) Diving Moment	Drag co-efficient with elevator at zero	Approximate speed with maximum propeller efficiency (ft./sec.)	Propeller efficiency	Approximate speed with correction for propeller efficiency (ft./sec.)	Equivalent couple on model	Approximate setting of elevator required to balance buoyancy couple at this speed	Lift coefficient with zero elevator setting	Dynamic Lift with zero elevator setting (lb.)	Lift coefficient with elevator setting as in table	Dynamic Lift with setting of elevators as in table (lb.)
0	0	1020	58				0				
2	−2000	1075	67 3	75 0	57 5		0	0400	318		
4	−5000	1086	50.0	73 8	66 6	+2400	0	0730	368		
6	−7400	1176	66.3	72 7	54 7	+3920	0	1200	600		
8	−9650	1310	63.2	71 8	52 3	+5600	0	1780	790		
10	−12400	1483	61 1	60 0	48 6	+7728	0	2690	960		
12	−14800	1697	49 0	67 2	47 0	+1.2380	−12°	2850	1022	.258	966
14	−17400	1658	46.5	66 6	44 6	+1 3500	−12°	3810	1130	306	1040
16	−19700	.2207	45 5	64 4	42 2	+1.7600	−24°*	.4210	1170	312	1020
18	−22100	2580	42 5	61 7	39 8	+2 1600	−24°	4720	1122	656	1020
20	−24400	2698	40 5	60 0	37 8	+2 6500	−24°	.5150	1130	397	1090

* At these angles couples obtainable from elevators are insufficient to maintain the angle of pitch

not only with the altitude or angle of incidence of the ship, but also with the setting of the elevators, which may have to be placed at a considerable angle so as to counteract the buoyancy couple

A separate calculation must therefore be made for each angle of incidence, as in the proceeding section for angle of incidence of 8 deg

For the sake of simplicity the engine is taken to deliver 75 hp throughout the working range, and the propeller to have an efficiency of 75 per cent at 40 m.p.h., and this efficiency to diminish to 50 per cent at 20 m.p.h. The drag, lift and pitching moment for the model S S Z are given in Tables I, II, and III.

The calculations are by no means rigorously exact, since to have them rigorously exact would require a very lengthy process.

A study of these tables gives a number of interesting results. Thus, at smaller angles of pitch the restoring couple due to buoyancy is practically equal to the disturbing couple due to the natural instability of the airship. The elevators will scarcely have to be used at all to maintain any required pitch angle. At higher angles of pitch beyond 14 deg, comparing Table IV with Table III, it is seen that the elevators when displaced to as large a negative angle as is practicable, are not sufficient to counteract the restoring couple due to buoyancy. At such an attitude, it is essential to use ballonets, a moving weight, or a displacement of the car relative to the ship. The approximate speeds of the ship have been calculated with allowance made for decrease in propeller efficiency with decrease of speed. The dynamic lift for each angle of pitch has been calculated with zero elevator setting (assuming moments to be provided by ballonets) and with definite negative settings of the elevators. When the elevators are considered as being at zero there is a definite maximum dynamic lift in the neighborhood of 14 deg. If the elevators are set at a negative angle apparently the maximum dynamic lift occurs at about the same angle.

It is interesting to note the maximum dynamic lift is (1170/4650) 100 = 25 2 per cent of gross lift, indicating that the airship can make with ease a clean get-away without initial use of ballast, and could achieve theoretically quite a respectable ceiling without use of ballast.

Increase in Ceiling Possible for the S. S. Z. by Means of Dynamic Lift

With ballonets of 500 cu. m., the proper proportion of ballast is 550 kg. Assuming this to be carried, and the volume of airship to be 66,500 cu. ft., the gross weight is $\frac{66{,}500 \times 1\,1}{1.308 \times 27}$ = 2080 kg.

By the law of delestage

$$H = 18400 \log \frac{2080}{2080 - 550} = 2480 \text{ m.} = 8000 \text{ ft.}$$

is the static ceiling.

If the engine torque is taken as directly proportional to the density, then if approximately the same r. p.m. is maintained at altitude, the speed of the airship will remain approximately the same at altitude. This is the most conservative assumption to make and only with an engine specially designed or adjusted for altitude work would it be possible to increase the speed at altitude. Under such a condition, the dynamic lift would vary directly as the density.

If H = dynamic ceiling in m.

$$H = 18400 \log \left(\frac{F}{F - f - L}\right)$$

where F = total gross weight initially = 2080 kg.

f = ballast = 550 kg

L = dynamic lift at the ceiling = $L_o\rho$ where ρ is density at the ceiling

L_o = dynamic lift at ground altitude = 1170/2.2 = 532 kg (as calculated in previous paragraphs)

F = 2080 kg.

This equation can be readily solved by a process of trial and error, and the solution is approximately 4200 m. The theoretical dynamic ceiling is therefore approximately 1720 m. greater than the dynamic ceiling.

Contribution of the S. S. Z. Hull to the Lift

The airship model tested, as illustrated in Figs. 1 and 2, is equipped with horizontal tail surfaces of approximately 9800 sq. mm. Neglecting the lifting effect of the car and rigging, Table V gives an idea of the proportion of lift due to the hull alone —

TABLE V

Angle of Pitch	Lift of Hull at 40 ft./sec.	Lift of Hull as percentage of gross lift	Lift of completely rigged ship elevators at zero	Lift due to horizontal surfaces car and rigging
0	0.000		0.006	0.006
4	0.022	33 2 per cent	0.079	0.056
8	0.046	26 8 per cent	0.173	0.131
12	0.090	26 per cent	0.284	0.298
16	0.169	33 2 per cent	0.421	0.281
20	0.091	19 8 per cent	0.515	0.312

From this table it is evident that for a non-rigid ship of standard design, the lifting effect of the horizontal tail surfaces, car and rigging is two or three times as great at 12-14 deg incidence as the effect of the hull. It is therefore mainly by the action of the horizontal tail surface that dynamic lift may be obtained at those altitudes at which a ship will be placed to obtain maximum dynamic lift.

N. A. C. A. Reports

Preliminary Report on Free Flight Tests. Synopsis of Report No. 70 National Advisory Committee for Aeronautics.

A report of the free flight tests conducted by the National Advisory Committee for Aeronautics to determine some of the characteristics of two full sized JN-4H airplanes. The maximum lift coefficient was found to be about 15 per cent higher in free flight and came at about 4 deg larger angle of incidence than on the model, and it was possible by using full power to just reach the burble point in level flight. The machines in landing did not exceed an angle of about 12 deg so that the landing speed deduced from the maximum lift coefficient of the model will in this case give the landing speed very closely. The maximum L/D of the machines was between 7 and 8 which is very near to that of the model. The velocity of the slip stream was determined for several motor speeds and the results agreed well with theoretical values. The longitudinal stability with locked and free controls was investigated for a JN-4H and also a DH-4. While the former machine was found to be quite unstable, the DH-4 was stable.

Wind Tunnel Studies in Aerodynamic Phenomena at High Speed. Synopsis of Report No. 83, National Advisory Committee for Aeronautics.

A great amount of research and experimental work has been done and fair success obtained in an effort to place airplane and propeller design upon an empirical basis. However, one cannot fail to be impressed by the apparent lack of data available toward establishing flow phenomena upon a rational basis, such that they may be interpreted in terms of the laws of physics.

With this end in view it was the object of the authors to design a wind tunnel differing from the usual type especially in regard to large power and speed of flow, which involves features whose suitability cannot be predicted. After all available information has been secured on full size and model wind tunnels in various parts of the world, there remains much obscurity about the air flow phenomena. It is the assumption of Dr. George de Bothezat that the type of air flow which establishes itself is governed by the stresses set up in the air passing the aerofoil. The unit stresses increase as the velocity rises, and it is easy to conceive that a given type of flow is possible only so long as the shearing stresses developed in the fluid do not exceed a certain magnitude, which depends on the value of the viscosity coefficient.

Experimental investigation of the flow has heretofore been rather unsuccessful because of lack of adequate methods. The writers laid out the design of the McCook Field wind tunnel to investigate the scaling effect due to high velocities of propeller aerofoils. During the course of the experiments, however, it was found possible to visualize the air flow by the following method: The velocities of the air flow discovered by the writers offers a solution to one of the fundamental problems of aerodynamics. This problem is the quantitative empirical measurement of the phenomena of fluid dynamics pertaining to flight and air flow. The method described in the report for visualizing air flow depends upon the fact that the moisture in the air condenses as a fog when the temperature is reduced to the dew point, provided that there is a solid or liquid nucleus to start the condensation. In the McCook Field wind tunnel the temperature drop is brought about through expansion of the air during acceleration, due to a drop of pressure of 100 inches of water. The relative humidity of the atmosphere can be artificially raised if too low, and the necessary nucleus for condensation is provided by the model tested. Flow vortices become readily visible, and the report contains many photographs showing the air flow past an aerofoil under different conditions.

The New Goodyear Pony Blimp, Which is Equipped With a Cabin Car Accommodating Three Persons

The Packard 500-600 Hp. Aircraft Engine

The Packard 1 A-2025 aircraft engine is the design of Col. Jesse G. Vincent, who was one of the creators of the Liberty motor, and is now vice president of engineering at the Detroit plant of the Packard Motor Car Co., where the engine was built. His experience with aviation during the war gave him opportunities for study of the actual performances not only of the Liberty engine but of the best engines produced in England, France, Italy and Germany. His study of the weaknesses and strong points of these various engines and his knowledge of American quantity production methods have been combined to produce the present motor.

In this motor Colonel Vincent completes a series of three engines which were designed to meet all normal aviation needs. This is the largest, and is intended for either high speed or for heavy load carrying. Its combination of light weight and high power gives it an exceedingly wide range.

This engine in the main follows along established lines of the Packard aero engines. It has twelve cylinders, set in blocks of six at an included angle of 60 deg. The cylinder bore is 5¾ in. and the stroke 6½ in., while the total piston displacement is 2025 cu. in., from which the engine takes its name of "Packard 2025."

The engine weighs only 1.94 lb. per hp., and with water, piping and radiator 2.275 lb. per horse-power, being thus the lightest in proportion to its power of any standard engine. The actual weight with propeller hub, carburetor, generator and ignition equipment is 1,118 lb. A properly designed nose radiator weighs about 130 lb., the water in it 52 lb., and the water in the cylinder jackets, circulating pumps and pipes 58 lb., giving a total weight for the power plant of 1356 lb.

Specifications

Detailed specifications are:—

Piston clearance 0.020 in. Three rings above piston pin and one below it. Piston pin of floating type.

Longitudinal center of gravity ⅝ in. behind the center line of the engine.

Valves.—Two inlet and two exhaust per cylinder, an innovation which will be discussed in detail later. All valve ports 2 in. in diameter. Exhaust valves lift ⅜ in. and inlet valves 7-16 in.

Compression ratio 20 per cent.

Ignition full advance is 45 deg. early and full retard 9 deg. late.

Inlet valves open 10 deg. after top center and close 45 deg. after bottom center, exhaust valves open 48 deg. after bottom center and close 8 deg. after top center.

Crankshaft is of seven bearing type, with bearings carefully proportioned to give uniform working life.

Connecting rods are of straddle type, carefully balanced and proportioned.

Pistons are aluminum die-cast, with floating piston pins. Center of piston head is supported and cooled by a pedestal resting on the piston pin.

Propeller hub is of quick-detachable type, designed with special care to prevent working loose or freezing on shaft.

Crankcase is of box-section type, split along center line of the crankshaft, and with the main bearings carried between the halves. Long through-bolts which unite the two halves serve the purpose also of giving a perfectly rigid unit.

Cylinders are of individual steel type.

Camshaft and rocker-arm assembly is enclosed, with special devices to prevent leakage.

Lubrication is of full pressure feed type, operating with a dry sump.

Radiator, according to design, is of nose type, but the engine is equally adaptable to any other type of cooling system.

Ignition is of improved Delco type, in which the distributor heads remain stationary and the spark advance is obtained by advancing the drive shaft. Complete double ignition to two sets of spark plugs is provided and the engine will perform excellently on either.

Throughout the design of the engine the utmost pains were taken to insure accessibility of all working parts and ease of installation. As a result, the engine is believed to be the most accessible of any of its type yet built. The distributor heads, for example, are easily reached from either side of the fuselage, and the water pump is at the bottom of the rear end of the crankcase.

Carburetor

The most important new development is in the location of the carburetor, which has been placed at the bottom of the crankcase and outside it. This arrangement provides great accessibility, and saves considerably in the weight of tubing and feed pump since it gives gravity feed with a minimum of piping. Most important, it makes the engine entirely fireproof so far as the carburetor is concerned since all vents are outside of the cowling.

Another important innovation is the use of a single duplex carburetor instead of two, as has been the practice. This carburetor is of the double-venturi type with an improved altitude control, and is, of course, equipped with the Packard fuelizer, which insures perfect combustion even with very poor grades of gasolene and gives the aviator the great advantage of being able to start his engine when it is cold after a long dive.

"We considered it more or less of an experiment to attempt the use of a single duplex carburetor," says Col. Vincent of this layout, "because we had no data to show whether the arrangement would give us good distribution and maximum power. There were so many overwhelming arguments in favor of a single carburetor, however, that it was decided to make the attempt, and it is most gratifying to note that the results certainly justify the design.

"The data which the tests have given us in regard to power output, gasoline economy and inlet manifold depression show a very satisfactory result. I think it very doubtful whether two carburetors could have done better in these things. And in all others the advantages in favor of the single carburetor are great.

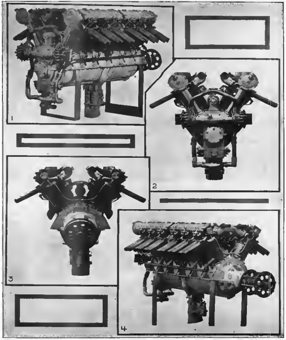
"There has always been a serious trouble in synchronizing the throttle control, as well as the altitude control, of two separate carburetors, and in this way alone the use of a single carburetor can be considered a distinct advance. It is also a great advance from the point of view of installation and maintenance because it permits gravity feed, eliminates piping and other weight, and particularly, because of its fireproof design. It is a change which certainly should commend itself at once to the airplane engine designer."

Valve Gear

The biggest mechanical advance has been made in the introduction of four valves and in the rocker-arm and camshaft mechanism. A double finger handles each pair of valves together and provides an even unit pressure on the rocker-arm bearings which shows in their perfect condition after long use. The enclosed type of assembly of this mechanism used was developed by Packard engineers under Col. Vincent's direction before the war and was contributed to the Liberty motor. It has now been further improved to insure better lubrication and greater tightness. A design which provides a bearing on either side of the rocker-arms, a device for sealing the openings at the outer ends of rocker-arm journals, and the small clearance which these make possible at this point have resulted in producing an assembly which in the matter of leakage of oil puts this engine distinctly ahead of its predecessors.

The individual cylinder, again of the type which was used in the Liberty motor, but with improvements, was also developed before the war in the Packard plant. It is now generally recognized as being among the best that have been designed because it has the best possible water circulation and therefore the best valve cooling, with the result that, as has been shown in the performance of the Liberty motors, valve trouble is practically eliminated.

The accuracy of the design and the perfect balance of the new engine was remarkably vindicated when it was put under test. It was put on the testing jacks exactly as it came from the assembly department and not a single change or adjustment of any kind was necessary except in the carburetor. After this had been set, the engine went through the entire test without adjustment of any kind and without developing any weakness or trouble. There was not a trace of fouling of



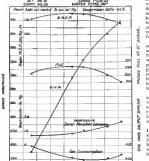
Four Views of the 500-600 Hp Packard Aircraft Engine.—(1) Three-Quarter View, Magneto End, (2) and (3) Magneto and Propeller End Views; (4) Three-Quarter View, Propeller End.

the spark plugs. The test sheet, published herewith, was made from the first engine of the type on its first run.

Power Output on Block Test

The engine, after it came from the assembly department, was run for 15 hr on a lapping-in jack, being driven by an electric motor. It was then run under its own power for 20 hr at about 500 r.p.m. The tests were then made, a 400 hp Sprague dynamometer being used. The smoothness of the engine was remarkable, especially at the higher speeds above 1500 r.p.m. So far as could be judged on the dynamometer, the acceleration was smooth and fast. At 250 r.p.m the engine idled very nicely.

The power curve shows that the engine developed 400 hp. at 1235 r.p.m., went to 500 hp. at 1570 r.p.m. and reached a maximum of 585 hp at 1925 r.p.m. It was thought inadvisable



Performance Chart of the 500-600 Hp Packard Aircraft Engine

to push the tests beyond this point both because of the limitations of the testing apparatus, which was already heavily overloaded, and because this was the only engine of the type so far ready. But the power curve assures a development of 600 hp. at 2000 r.p.m.

When the carburetor was adjusted for maximum power output, the engine showed a gasoline economy of .5 and .52 lb per hp./hr. But with adjustments to give a slightly smaller power, it proved possible to get an economy as low as .45 lb. Because of the risk of overheating the dynamometer it was thought unwise to make a prolonged run at high speed, but the oil consumption indicated is from .01 to .03 lb per hp./hr.

The engine was completely disassembled and a very careful examination of all the working parts was made after the tests had been concluded. All the parts were found to be in first class condition throughout. The piston clearances had been ample, as it was found that the cylinders showed evidences of perfect lubrication. The rocker-arm journals were in excellent condition and the camshaft housing showed no evidence of galling at the bearings, undoubtedly due to the use of the bearing on both sides of the rocker-arm.

These preliminary tests were so satisfactory that when the motor was delivered at the aviation field, the engineers there decided that further ground tests were unnecessary although it had been planned to make them. The work of installing the engine in a high speed airplane, just completed, was begun at once, and flying tests will probably be under way before this article is printed.

Col. Vincent's wide experience and high reputation enable him to speak with authority even concerning an engine of his own design, in spite of his natural interest in it. He is greatly pleased with the performance of this engine and predicts a wide use for it.

"The tests so far made fully justify the expectation of great speed from this motor," he said. "However, it is not primarily designed for racing, but for a wide and varied range of duties where high power is required or where high reserve power is desirable. The power curve indicates that this engine can be used in many different types of planes, and its comparative lightness and its smoothness at high speeds contribute greatly to its usefulness. It will have many advantages over any other type of engine with which I am familiar for all duties which require great power. Its flexibility makes it available for either heavy loading or high speed.

"For instance, this motor will be most suitable for the type of plane which we used in the war for night bombing, and which in commercial use would carry several passengers or freight. Such a plane would be a slow-moving machine and would need 400 to 425 hp. This engine will develop this power at around 1275 to 1350 r.p.m., and at this speed a very great propeller efficiency can be secured and the life of the engine will be greatly prolonged. Under such conditions I believe this engine will have a very long life, and it ought to give around 250 hr. flying without needing overhaul of any kind.

"The engine will be equally useful for the faster plane such as was used for day-bombing, or as will be used for mail with the development of the aerial postal service. The 475 hp or more needed for this would be developed at about 1500 r.p.m. and there would still be a reserve power of some 125 hp for use in case of emergencies, which is enough to meet almost any conditions.

"For speed the engine has its 600 hp. to give at 2000 r.p.m. It also has great endurance and reliability, as the tests have shown, so that there need be little fear of failure of performance. Its lightness makes it possible to mount it in a light low resistance plane, and it is more than safe to assume that some startling results in the way of high speed will be obtained.

"The greatest value of this engine, of course, will be in the commercial field, since it is toward that field that America must look for its future in aeronautical work. This is not and never has been a military nation, and we can be quite certain that Congress will never provide for the military air service the money which would permit the proper development of aeronautics. Yet this country will never be safe until we are able to dominate the air above it in case of emergency.

"This development can only come from the commercial field, and to insure it, commercial aeronautics must be placed on a financially sound business basis. Efficient and economical engines like this, which will make commercial aeronautics profitable, are therefore important factors in bringing about this necessary result."

Farman Goliath in 24-Hr. Flight

A Farman Goliath, piloted by Lieutenants Bossoutrot and Bernard, on June 4 broke the world's duration record by remaining in the air without landing 24 hr. 19 min. 7 sec. and covering a distance of 1,915.2 km. (1,196 miles).

The Goliath also established what are claimed to be records for 1,000 and 1,500 km., by covering the former distance in 11 hr. 20 min. 56 sec., and the latter in 16 hr. 42 min. 8 sec.

The former official world's duration record was established on June 28, 1914, by W. Landmann, who flew for 21 hr. 48 min. 45 sec.

Aeronautic Instruments

By Mayo D. Hersey

(Concluded from our last issue)

Design, Development, and Production

The design of aeronautic instruments is at present almost wholly on a cut-and-try basis. The Bureau of Standards has made some progress, however, in placing instrument design on a rational basis. Consideration has been given to such general problems as the stiffness of elastic systems where two bodies such as a spring and diaphragm are coupled together, the effects of temperature and elastic lag on coupled systems, bimetallic bars for temperature compensation, the balance of moving parts to resist angular acceleration and vibration, the securing of a uniform scale by suitable design of transmission mechanism; and the treatment of aerodynamic problems and the general action of damping fluids by the method of dimensions described before this Society by Dr. Buckingham at the Buffalo meeting in 1915 in his paper on Model Experiments.

Experimental development has to follow the preliminary design of an instrument before it can be put into quantity production. It is here that the physical laboratory, in immediate conjunction with an instrument shop suitably equipped with watchmaker's tools in addition to the ordinary machine tools, plays an essential part. Among the recent development projects of the Aeronautic Instruments Section at the Bureau of Standards may be mentioned the following several of which were undertaken at the request of the Air Service or the National Advisory Committee for Aeronautics:

(a) The conversion of barographs from a low altitude to a high-altitude range by the addition of a suitable external spring, together with the development of recording processes to eliminate the use of ink.

(b) The conversion of altimeters from an altitude scale to a pressure scale by the modification of the mechanism and engraving of special dials, so as to adapt them for aircraft performance testing. In connection with this work improvements were also made in the method of mounting the main spring of commercial altimeters so as to diminish the observed differences between readings with increasing and decreasing altitudes, or hysteresis as it is commonly called.

(c) The development of a precision altimeter with a large dial giving a ½-in. movement of the pointer for each 100 ft. of altitude. In order to justify such high precision of reading, that is, such high sensitivity or openness of scale, a special design had to be made for the elastic system to diminish elastic lag. This was accomplished by making the steel main spring so many times stiffer than the diaphragm that the resultant action of the instrument is practically independent of the quality of the material in the diaphragm.

(d) The development of a direct-reading, rate-of-climb indicator based on the capillary-tube-leak principle, but in which the use of a liquid has been entirely dispensed with through the use of sensitive diaphragms.

(e) Development of a reduced-scale working model of a proposed gyro-stabilizer on the long period pendulum principle, possessing mechanical features of extreme simplicity.

(f) The application of the moving picture camera, by means of an automatic timing mechanism, for the purpose of securing a record of instrument readings during the performance test of an aircraft in flight. The whole outfit, instruments, illumination, camera and timing-system, is self-contained and forms a unit which takes the place of the human observer in the airplane.

(g) A working model of a type of dynamical ground speed indicator which would become available if there existed a suitable gyro-stabilizer to hold it horizontal. This model consists of a large steel ball free to roll back and forth in a glass tube filled with a viscous liquid. It can be shown mathematically that if the fluid resistance is directly proportional to the speed of the ball through the tube, while the tube is held in a horizontal fore-and-aft position, then the displacement of the ball at any instant from its initial position in the tube is directly proportional to the absolute ground speed of the aircraft.

The development work on any given model of an instrument must be dropped and the design rigidly fixed before quantity production can be efficiently carried on. In this country the quality of products made in quantity has to be artificially held up to standard by means of specifications and inspection. This situation is not so commonly met with abroad, especially in France, where every individual workman, from the mechanic in the shop up to the head of the concern, takes a professional artistic pride in the quality of his output. This difference is not the fault of the American manufacturer, and there are some advantages in our system, yet the fact remains that in Europe, instrument production has been successfully carried on without specifications. This spectacle of successful instruments formed one of the most astonishing impressions which the writer gathered from his trip to Europe during the war.

II. Testing of Instruments

The testing of any aeronautic instrument consists in general of a direct comparison with some suitable standard, the instrument being operated from point to point over its full scale, the whole procedure should then be repeated under different temperatures or other important conditions varying in flight. The most important of these conditions are

(a) Extreme low temperatures
(b) Change in pressure or density of air
(c) Acceleration and inclination
(d) Vibration
(e) Time elapsed during the flight.

A typical installation of testing apparatus, in this instance for the testing of tachometers, is shown in Fig. 4. The results of each a test are ordinarily given out in the form of tables or curves showing the correction of the instrument from point to point of its scale. By the correction is meant the amount that has to be added algebraically to the reading of the instrument in order to give the true value of the quantity measured. Typical correction plots or curves of this sort are seen in the first two charts shown on Fig. 5.

There are various degrees of refinement possible in the testing procedure, and instrument tests may be classified as follows

(a) Factory inspection tests
(b) Short test for service instruments
(c) The Bureau of Standards general test
(d) More thorough tests on sample instruments
(e) Special tests on experimental instruments
(f) Reproduction of the flight history

Factory inspection tests can be reduced to a comparatively simple routine after the first few instruments of each pattern have been inspected. In some cases it is permissible to determine simply the corrections at one or two points on the scale, and to omit some parts of the test entirely, except on a prescribed number of samples selected at random from each lot. The purpose of such tests is to control the quality of the output so as to maintain the standard of performance agreed upon in the specifications.

The *short test for service instruments* is an attempt to secure, in a minimum time, such data regarding the maximum calibration correction or temperature effect as may be needed for actual reference in connection with the installation or use of instruments on aircraft.

The *Bureau of Standards general test* is the one which is furnished on instruments submitted to the Bureau without special instructions. It is a comprehensive standard form of test affording a complete calibration curve together with, at least, numerical values for the effects of errors due to temperature and other well known conditions. The data from this general test are sufficient for calculating the probable performance of the instrument under any given set of flight conditions. However, when those conditions are actually known, more exact results can be obtained by carrying out the flight-history tests described under (f) below

* Abstract of a paper read before the American Society of Mechanical Engineers

The Bureau makes *more thorough tests on sample instruments* of new type whose mechanism is not familiar. Such additional observations usually include some form of *accelerated life-test*, such as a five-day run to determine the endurance of the instrument under vibration. For this purpose adjustable vibrating stands have been made which reproduce the condition of vibration of an airplane instrument board. The steadiness of the pointer and the accuracy of the instrument with and without vibration are also observed in connection with such a test.

The *special tests on experimental instruments*, depend, of course, on the nature of the work for which the instrument is to be used, and on the flight conditions which will prevail. The readings in such a test may have to be taken to a higher degree of precision than usual, and may require specially refined standards.

For instruments such as aneroid barometers, which involve serious errors due to elastic lag or temperature lag, there can be no more reliable method of determining the corrections necessary for the interpretation of the readings than to make a *flight-history* test by actually reproducing in the laboratory the identical variation of pressure, temperature, etc., which was experienced from time to time during the flight. This is particularly important in connection with the use of barographs for competitive altitude flights. It is now well known that barographs subject to any appreciable amount of elastic lag will read a higher altitude the greater the time elapsed during the flight.

It is a short step from some of these more complete testing methods to the general subject of the experimental investigation of sources of error on instruments. Such investigations have formed one of the most interesting features of the work of the Bureau of Standards and are illustrated by Figs. 5 and 6, which are based on experiments with high-grade aneroids.

In Fig. 5 the first chart *(a)* shows the ordinary calibration of an aneroid changing the pressure at the rate of an inch of mercury in five minutes. (At sea level one inch of mercury corresponds to about one thousand feet of altitude. At twenty thousand feet one inch corresponds to about two thousand feet of altitude.) The calibration curve would be distinctly different at some different speed, due to elastic lag in the corrugated metal vacuum boxes. For the same reason, as shown in the second chart *(b)*, the discrepancy between the readings going up and coming down is much greater when the aneroid is held at the maximum altitude for a considerable time interval. This drift, or change of reading at constant pressure, is shown in the third chart *(c)* as a function of the time elapsed. Such curves may be taken as a criterion of the elastic quality of the material in the instrument, and several hundred such have been determined in the course of the Bureau's investigations. The curves in Fig. 6-A show the increase in the width of the hysteresis loops with rise of temperature, and it also shows the decrease in the sensitivity of the movement when an instrument is chilled. This last effect is largely due to the change of elasticity with temperature, and cannot be fully compensated for by means of the ordinary bimetallic lever. The remaining curves, Fig. 6-B, show, on the other hand, what can be done in the way of temperature compensation. One represents a typical uncompensated aneroid. The graph shows the change of reading with temperature at a constant pressure corresponding to sea level conditions. Another shows a partial degree of compensation obtained by admitting air to the vacuum box. The third shows satisfactory compensation by means of a bimetallic bar so far as sea-level observations are concerned, but this same aneroid may have a serious temperature error when the movement has shifted into the new position which it will occupy at twenty thousand feet.

Still further characteristics of aneroid barometers have been studied at the Bureau in addition to those shown in Figs. 5 and 6 and similar investigations have been extended to all of the other aeronautic instruments.

Use of Instruments

Many practical airplane pilots disclaim the use of instruments, and certainly it is desirable that the aviator should be trained to become just as independent of any mechanical aid as possible. Yet it would hardly do to equip planes without all of the usual service instruments, for those instruments which one pilot thinks he can dispense with are precisely the ones the next pilot would insist upon having. And if the instruments are to be installed at all, even though they may not be read frequently, it is necessary for them to be reliable,

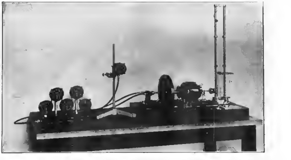


FIG. 4 TESTING OUTFIT FOR AIRPLANE TACHOMETERS

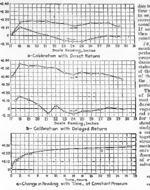


FIG. 5 EFFECT OF ELASTIC LAG ON ALTIMETERS

and so the whole subject has to be studied and put on a solid scientific foundation.

Some of the times when airplane instruments are really of the most importance are the following:

(a) For various military and naval operations such as bomb dropping.

(b) Long distance navigation

(c) Flying at night and in clouds

(d) Preparing to land on a perfectly smooth body of water where the height is deceptive

(e) Flying in formation with instructions to hold to a prescribed air speed and altitude

(f) Photographic and survey work.

The need for instruments is still more evident in airship work. Here it is necessary to control the position of the ship, especially near the ground, with comparatively greater precision; nor is it possible for the pilot to act so quickly in response to his unaided senses as it might be in an airplane.

The following precautions may be suggested for getting the best results in the practical use of service instruments:

(a) Select for installation in the first place only those instruments which can be certified by the Bureau of Standards as suitable for the intended use. Such approval will ordinarily depend more on the performance of each individual instrument as evidenced by tests, than it will upon the make or design.

(b) In any event see that the instrument is tested immediately prior to installation to avoid the occurrence of large errors due to secular changes or to mechanical injury. If the errors thus found are not considered negligible, a small correction card can be furnished with each instrument.

(c) Where accuracy is required in flight observations the aviator must refer to these corrections. He also must remember where appreciable lag errors, are stated to exist, whether due to elastic lag or temperature lag or other causes, that some time will be required for the instrument to completely respond to any given change, and that the results will be different with increasing and decreasing scale readings. Instruments are usually adjusted to be correct for increasing readings. If such instruments show an appreciable lag during the test, then in service they will tend to read too high when the pointer is falling.

(d) At least once in six months it is desirable that instruments should be overhauled, during which time they may perhaps be replaced by a reserve supply of fresh instruments properly tested and adjusted. Instruments which are visibly damaged or out of adjustment may be sent to some central station such as the Bureau of Standards for salvaging. Even if they are not visibly out of adjustment near the zero point of the scale, they may reveal surprising errors further up on the scale if properly tested, and this should be done periodically.

The problem of salvaging has been studied by the Bureau of Standards both in connection with the writer's official visit to the various aerodromes and salvage stations abroad during the war and more recently in connection with the salvaging of instruments for the Air Mail Service. The statistical results of such work are of the greatest value as a basis for future improvements in instrument construction, and should provide the raw material for important scientific study. The actual salvage proposition consists of dismantling a certain number of damaged instruments and putting them together again so as to form a smaller number of good instruments. The study of expedients for readjusting the mechanism forms an integral part of such work. This can only be done in the testing laboratory. Now unless it is early discarded in favor of some new type, it will be the destiny of every instrument that is manufactured to come back for salvage or readjustment eventually. Hence the facility with

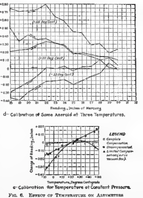


FIG. 6. EFFECT OF TEMPERATURE ON ALTIMETERS

which such readjustment can be made, is a criterion not to be overlooked in connection with the purchasing of instruments.

Such readjustments have to be made with due regard to securing a uniform scale and a satisfactory degree of temperature compensation. In some cases it is simpler to prepare new dials graduated empirically to fit the altered performance of the movement.

So much for service instruments. The use of supermantal instruments, on the other hand, is more obvious, since they do not form a part of the permanent equipment and are called for only when actually needed for special observations. The procedure for such observations is too elaborate to go into here except by way of illustration. Consider, for example, the use of the barograph for high-altitude determinations. The following is an outline of the procedure for determining

(a) The most probable altitude

(b) The official altitude for competitive purposes in accordance with the rules of the International Aeronautic Federation.

Whichever method of computation is to be used, only such barographs should be selected for the flight as have passed, or could pass, the performance requirements for a Bureau of Standards certificate. Particular attention should be given to the reliability of the clockwork, which is preferably such as to give a rapid movement to the drum; for example, one revolution per hour. The pressure scale should also be as open as possible, which means an extra tall drum. The whole movement must be rigid and strong. The pen must be adjusted without undue friction, but so that the ink will flow freely and trace a delicate but definite line. Charts graduated in pressure units are convenient, and must be of good quality.

Unless the barograph is practically free from temperature errors, a standardized thermometer should be attached to the barograph case and several readings taken during the ascent. And unless the barograph is also free from temperature lag, such a thermometer should be placed inside the case, with its bulb close to the vacuum boxes.

For the *most probable altitude* determination, two barographs may be taken, and the results averaged after all corrections have been applied. In this method, the pen may be adjusted before leaving the ground to read the true pressure as determined by a standardized mercurial barometer at the field. Readings of a good strut thermometer or thermograph should be obtained at least every 2000 ft. for the determination of atmospheric temperature distribution.

To determine the instrument correction at the starting point and at the ceiling by laboratory test after the flight, the flight-history method of testing should be used, that is the barographs should be put in a receptacle within which both temperature and pressure can be made to follow sensibly the same curves with regard to time that were experienced during the flight. By comparison with a standardized and fully corrected mercurial barometer, the true pressure corresponding to the base and ceiling readings can thus be found.

The altitudes corresponding to these two pressures are next to be found on the 50 deg. fahr. altitude-pressure table issued by the Bureau of Standards. By subtracting the base altitude from the ceiling altitude thus found, a figure results which represents the relative altitude above the ground on the assumption of an isothermal atmosphere at 50 deg. fahr. This fictitious altitude is then multiplied by a correction factor given in the Bureau of Standards tables, to correct the result for the true mean temperature of the air column. This mean temperature has to be computed in the proper manner. The derivation of the most general altitude formula from fundamental physical principles shows that the particular kind of a mean temperature which is needed here, is the arithmetic mean of a series of temperatures equally spaced with regard to the logarithm of the pressure, or what amounts to the same thing, equally spaced with regard to the isothermal 50 deg. fahr. altitude. It would not be correct to take the mean temperature for equally spaced intervals of pressure. To the altitude thus obtained, there has to be added, finally, the official altitude of the base station above sea level.

For the determination of *competitive altitudes* by the International rule, it is only necessary to carry up one barograph, and no strut thermometer is required.

Purely instrumental corrections may be obtained as before but the method of computation is different. This method of computation is very much simpler than the other, in that it does not require any record of the atmospheric temperature during the flight. It consists of a direct substitution of the true ceiling pressure into the International formula. This formula is a definite relation between pressure and altitude involving only numerical constants. It was based upon sounding balloon observations taken in Europe.

In the use of this method, it is understood that the barograph pen should be adjusted, at the start of the flight, to read whatever pressure corresponds to the known altitude of the station by reference to the International formula.

Conclusions

In concluding this paper, a recapitulation may well be made of some of the outstanding problems of instrument development, the solution of which is much to be desired.

(a) A satisfactory gasoline depth gage is needed.

(b) Barographs and other recording instruments of better quality than any now existing are needed. Better clockwork, and a much more open scale, and more complete freedom from errors due to friction, temperature, elastic lag, and lack of balance are desirable.

(c) A wholly satisfactory form of compass for airplanes is not as yet available. Besides the northerly turning error, so-called, to which all single-pivot compasses are necessarily subject, there are troubles due to the action of the damping fluid.

(d) Air speed indicators suitable for the low speeds of airship flight are required.

(e) A gyro-stabilizer is needed, different from existing types in that it must be able to stabilize a body which is not rigid, but contains a freely moving mass. Such a stabilizer is necessary before the full possibilities of any dynamical type of ground-speed indicator can be realized.

The material in this paper is of course not due to any one individual, but is based upon the work of the entire Aeronautic Instruments Section of the Bureau of Standards. Later, the detailed official reports prepared by the various members of the staff concerned, should be available through the publications of the Bureau and the National Advisory Committee for Aeronautics.

CONSTRUCTION OF THE CABIN OF THE VICKERS COMMERCIAL AIRPLANE
Wide World Photos

The Efficiency of Airplane Struts

By Wallace F. Wiley

In airplane design it is advantageous to have some method of comparing the power absorbed by struts of various shapes and materials, so that, for the velocity under consideration, the most efficient strut can be used. This is based on the assumption that, at the given velocity, the most efficient strut of a series, all of which are of the same length and which have the same final strength, is the one which absorbs the least power. It is the purpose of this article, therefore, to establish the general equation for the power absorbed by a strut of any material, section, length and strength at any velocity, and to show how this equation can be applied.

The following symbols will be used

a = area of strut section in sq. in.
b = breadth of section normal to wind in inches
l = length of strut in inches

$$n = \frac{a}{b^2}$$

$$m = \frac{k^2}{b^2}$$

k = radius of gyration of section
P = total power absorbed by strut
V = velocity in m.p.h.
ρ/g = density of air/acceleration of gravity = .00238
C = absolute resistance coefficient of section
E = modulus of elasticity of material
w = weight of material in lb./cu. in.
r = lift/drag ratio of plane
F = final strength strut in lb.
A = projected area of strut normal to wind in sq. in. = $l \times b$

The power absorbed by a strut consists of two parts, one of which we may call the weight power, and the other the resistance power. The weight power can be considered as that power required to force through the air at the given velocity a lifting surface just large enough to support the weight of the strut. The resistance power is the power required to force the strut itself through the air. The total power absorbed, then, is the sum of the two powers.

$$\text{The weight power} = \frac{wlaV}{375r}$$

$$\text{The resistance power} = \frac{CAV^3\rho/g}{375 \times 144}$$

$$\text{Then } P = \frac{wlaV}{375\,r} + \frac{CAV^3\rho/g}{375 \times 144} \qquad (1)$$

$$\text{But } \frac{F}{a} = \frac{8.72\,E}{(l/k)^2} \text{ or } k^2 = \frac{l^2F}{8.72\,Ea}$$

Now $a = nb^2$
And $k^2 = mb^2$

$$\text{Therefore } mb^2 = \frac{l^2F}{8.72\,Enb^2}$$

$$\text{Or} \qquad b = \sqrt[4]{\frac{l^2F}{8.72\,Emn}} \qquad (2)$$

$$\text{And} \qquad a = n\sqrt{\frac{l^2F}{8.72\,Emn}} \qquad (3)$$

Then from equations (1), (2) and (3)

$$P = \frac{wlnV}{375\,r}\sqrt{\frac{l^2F}{8.72\,Emn}} + \frac{ClV^3\rho/g}{375 \times 144}\sqrt[4]{\frac{l^2F}{8.72\,Emn}}$$

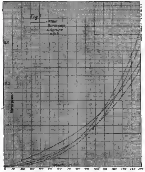


FIG. 1.

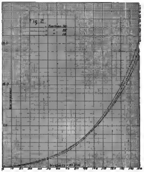


FIG. 2.

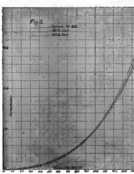


Fig 3

$$P = \frac{WV}{375}\sqrt[4]{\frac{CF}{8.72\,Fmn}}\left(\frac{wn}{r}\sqrt[4]{\frac{CF}{8.72\,Emn}}+\frac{CV^2\rho/g}{144}\right)\ldots(4)$$

which is the general equation for the power absorbed by any given strut.

The figures show the application of formula 4. The lift/drag ratio for the theoretical supporting plane is taken as 6

Fig 1 represents the power absorbed by struts of spruce, ash, steel and duralumin of strut section Ogilvie No 30, length 72 in and final strength 1000 lb It will be noted that for this particular strut form the duralumin strut, due to its greater weight, is less efficient than the spruce strut at velocities lower than 100 m.p.h., but, on account of its higher modulus of elasticity and consequently smaller projected area, is more efficient at greater velocities. In Fig 2, the graphs plotted are for Ogilvie sections 10, 30 and 35, material spruce, length 72 in and final strength 1000 lb In Fig 2, graphs are plotted for section 30 with four other sections the same as 30 externally, but with material removed from the center to a depth of 40 per cent and 80 per cent respectively of the external breadth of the section In these cases, the total power up to about 90 m.p.h decreases with the amount of material removed, but increases at higher velocities, due to the increased external breadth

The Fairchild Automatic Camera

The new Fairchild Automatic Aerial Camera, Model A, embodies the latest and most approved ideas in the line of an automatic mapping camera. The magazines, which are detachable, have a capacity of 75 ft. of 24 cm film (9-7/16 in) giving a total of 108 exposures. Each magazine contains a device for equally spacing the exposures upon the film, that is the margin between the pictures is kept uniform, in this manner the waste of film is kept at a minimum. The connection between the magazine and the camera is made by a self-centering clutch, which enables the operator to set the magazine in place in the camera without the necessity of previously locating the connections. This makes for speed in changing magazines.

The shutter is of the well-known Fairchild High Efficiency Between-the-Lens type having an *actual* speed of 1/40 to 1/150 sec

The mechanism for operating the camera is located in the top of the cone, easily accessible The drive is by motor This motor can be fastened direct to the camera and connected, as in the Government types, by a flexible shaft. The power is furnished by a 12 volt storage battery.

This camera has an attachment whereby, if the power should fail, it can be operated by hand at the same speed and power, thus keeping the interval between exposures the same as though driven automatically

The cones or snouts are of one piece of aluminum spun into shape, there being no seams nor projections to hinder placing it in its mount

The intervals between exposures are controlled by a separate unit, which can be placed anywhere in the plane This control can be set at any interval and once set is positive. It embodies not only a device for regulating the intervals between exposures, but also a switch for stopping, starting and for throwing the camera over into hand control, a pilot light, which flashes when the shutter releases, a counter to indicate the number of exposures and a button for use in taking individual pictures.

The entire camera has been designed to do away with all intricate mechanisms that have been so common to automatic cameras, to give, when operated automatically, a roll of perfect overlapping pictures, to furnish a means of taking one roll after another without breaks in the train of exposures and, finally, to do away with all the distortion that has heretofore manifested itself in these cameras.

The standard focal length is 12 in and a choice of Cooke Aviar, Bausch & Lomb Tessar, Aldis, Berthiot or Carl Zeiss f 4.5 lenses is given

New Fairchild Aerial Camera, 18 x 24 cm

Airship Suspensions

By Ralph H. Upson
Chief Aeronautical Engineer, Goodyear Tire and Rubber Co.

As a matter of definition the word "suspension" is used to designate the means by which the car of a non-rigid airship is attached to the envelope. This comprises the cables and any incidental cordage, together with their attachments at each end

The earliest form of suspension was by means of a net which passed over the entire envelope. This is still commonly used on free balloons on account of its simplicity, convenience, and the fact that the resistance in this case is hardly an item to be considered

Before the war nets had become largely obsolete on airships, but the best suspensions were still very complicated. The general system as then used consisted of a multiplicity of cables, each one further sub-divided several times, terminating at the envelope in hundreds of small cords which were usually attached to a heavy band or loop passing horizontally around the balloon. This type of suspension was retained on kite or observation balloons up to the very end of the war. The purpose, of course, was the obvious one of distributing the stresses as uniformly as possible over the surface of the fabric, but the system was complicated, heavy and subject to frequent breakages, due to the large number of small cords and attachments, and most serious of all, the resistance was found to be literally enormous. Tests indicated that these airships commonly had a total resistance over four times what would be anticipated from the envelope alone A large part of this extra resistance was clearly due to the suspension.

It is impossible to say who first appreciated the great

Goodyear Finger Patch

importance of cutting down this parasite resistance. It was a natural development that took place nearly everywhere as aerodynamic knowledge and the results of wind tunnel experiments became known. In this country we were faced almost at the outset of our airship construction program with the practical necessity of improving the cordage and band type of suspension which was standard at that time.

A thorough study of the subject was made, new ideas of all kinds collected and tested and the result was the so-called finger patch, which in all essentials has remained the same ever since. The principle behind this patch is extremely simple. It is only a means of accomplishing, in and on the fabric itself, what was previously accomplished outside In other words, instead of distributing the stress to the fabric by means of a multiplicity of divided and subdivided cords, we lead the stress directly to the envelope in more concentrated form and distributed it on the surface of the fabric itself

As usual, however, the fundamental idea was but a small part of the larger problem of actually designing a patch that would accomplish the desired purpose The ideal, of course, is to have a patch which develops practically the full strength of the fabric, and which is just strong enough to take its own fair share of the load This has been accomplished by proper adjustment of such variables as length and number of fingers, strength and distribution of strength along each finger, proper stretch at different points, the angle between fingers, and local reinforcements.

The actual dimensions and strength of any particular series of patches must be designed to suit the fabric on which it is mounted The design must also take into account the way the fabric is used, in other words, the relative circumferential and longitudinal stresses which occur in the balloon under different conditions. The patch here shown was designed for a particular balloon, and would not necessarily be ideal for other types and sizes. The same principle of construction, however, would still hold

Since the introduction of the finger patch other improvements in the suspension have been made which have still further increased its efficiency Rope has been entirely eliminated, steel cable being now used all the way to the envelope. Various connections have been improved, the upper bridle shortened and in many cases done away with entirely, and now the application of rubber streamline to the cables themselves promises to reduce the resistance still further. At almost every step the weight, although less important, has also been reduced. The strength and durability have been increased rather than decreased. Generally the patches are designed, when mounted on the proper fabric, to hold four times their normal flying load

The Stout Batwing Monoplane

The Stout Batwing monoplane is a giant wing in which are accommodated machinery, trussing, etc The engines are set into the leading edge, the passengers are enclosed between the surfaces of the wing section, and every part that is exposed to the air is designed to lift.

The central part of the wing is thick and of long chord, the tips thin and narrow. In fact, the ship follows more closely the butter-fly than the bird in its plan view, and gives more surface within smaller dimensions.

An experimental machine was first flown at Dayton in the spring of 1918 and this machine used for research and development work toward later models At present several commercial types of ships are being designed or are on the way, and some enormous planes intended for military use

The thick main wing is not only framed up entirely of veneer, but the surface as well is formed of this extremely tough and water-proof material. The veneer on the surface is three-ply and only 1/20 in. thick. The wings are strong enough however so that one can walk all over them as a sidewalk.

The radiators in this ship pull into the wings when high altitudes are reached, and the heat from them is utilized to warm the passengers and pilot. In the large type even the landing gear is pulled into the wing when the ship is off the ground, increasing its speed by about 10 m.p.h.

A new ship of this type being laid down has a span of 100 ft., and a wing depth of 7 ft. at the center. It has within it a compartment for mail, bombs, or passengers as the case may be, this cabin being 30 ft. long, 8 ft. high and 8 ft. wide.

The Advisory Committee for Aeronautics

The report of the Advisory Committee for Aeronautics (British) for 1918-19 which, although it is dated last August, has only just been issued, indicates how greatly the activities of the Committee have had to be expanded in order to cope with the many demands from the R.A.F. and the industry. The Committee has now reverted to its former practice of indicating some of the more important work carried out during the period under review, and the present report indicates not only the progress which has been made in aerodynamical research, but also in the manipulation of aircraft. It is pointed out, for instance, that as a result of the investigations carried out at the Royal Aircraft Establishment and the N.P.L., there is now practically no aspect of the complicated motion of spinning which cannot be explained and made the subject of calculation.

Experimental work in aerodynamics has covered a large field, and the performances of full-scale machines have been compared with the results obtained with scale models in the wind channel with a view to ascertaining the relation between the wind forces in the two cases. Other wing experiments carried out relate to biplane and triplane wings, stress distribution under special conditions of flight, aspect ratio, form of wing tips, effect of "wash-out," best form and dimensions of ailerons, balanced ailerons for large machines, etc. Measurements of the distribution of pressure over the wings of a biplane in flight have been made at the R.A.E.

Notable progress has been made in the establishment of a correct airscrew theory and in its application to design, and a summary of this work is shortly to be published. Useful work has also been done towards the production of propellers of variable pitch. The distribution of velocity in the air entering a propeller, and in the slipstream, has been carefully investigated.

Progress is reported in respect of airplane stability, both in theory and practice. Methods have been developed for the application of stability calculations to the more complicated motions of an airplane and from the knowledge gained some of the earliest conceptions have been revised. It is also pointed out that the practice has been established in the trials of new airplanes at Martlesham Heath of taking records to determine their longitudinal stability.

The determination of the aerodynamic data required for the computation of stress distribution has proceeded steadily, and new methods of tests for application to the actual airplane or its parts have been devised. It is pointed out that it has been the practice to make a test to destruction at the R.A.E. of one airplane of each new type.

Turning to airships the report points out that while the progress in airship construction has probably been relatively greater than that made in respect of the airplane, the advance in the study of airship theory and in the methods of experiment in relation to airships has been less marked. The measurement of the head resistance of an airship body, even in the case of a model, has been found to present many experimental difficulties, and the information obtained cannot be said to be yet by any means complete. The step from model to full-scale cannot at present be made with any approach to the accuracy requisite. It is pointed out that research work in regard to airships is bound to be expensive, but it is hoped that the Committee will not be hampered in this highly important work by financial worries. Important progress has been made in the development of the theory of airship stability, and useful work has been carried out in connection with wind-screens and the mooring of rigid airships.

Experimental work in connection with kite balloons has led to important improvements in construction and performance.

While aerodynamic tests on seaplane models present no very distinctive features, a good deal of research has been carried out with floats and flying-boat hulls in the William Froude National Tank, resulting in the accumulation of a considerable amount of information for the guidance of designers. An interesting and important part of the work has been the investigation of the stability of a seaplane while planing, for which tests special apparatus was designed. Other tank experiments have included the determination of the best form of drogue to serve as a sea-anchor for airships.

Model experiments in the wind channel have been made in connection with the design of airplane carrier ships, mainly relating to the flow of air over the alighting deck, and the results have been confirmed by flying trials. An alternative scheme for an alighting stage consisting of a large number of longitudinal parallel wire ropes tensioned to as flat a catenary as possible, so forming a long flexible landing platform, has been suggested by Mr. F. W. Lanchester.

Extensive investigations have been carried out in connection with engines. It is claimed that the successful use of aluminum cylinders and pistons has been rendered possible by the researches on light alloys carried out at the N.P.L., the R.A.E., Birmingham University, and elsewhere with the close co-operation of the foundries experienced in such work. It is realized that much remains to be done to render the high-power aeronautical engine as reliable as those used for other forms of locomotion, and great part of the research work has been directed towards determining the causes of failure in practice, such as crankcase breakages, crankshaft failures, burning of valves, piston troubles, ignition, etc. The question of engine cooling has come in for a good deal of attention. This is an aerodynamic as well as an engine problem, and its solution must always be a matter of compromise. On air cooling a large amount of work has been done, and the radiator problem has been fully studied.

Another matter to which attention has been given is the determination of the loss of power with height, i.e., with reduction of air density, and generally the testing of engines under high altitude conditions. Means of reducing the loss of power at a height have been investigated, especially the question of super-compression, and the use of a blower to maintain the air pressure.

The work in connection with light alloys has proceeded on two main, but very distinct lines: 1. Wrought alloys of high tensile strength for rigid airship construction and other aircraft work where they can replace steel with a saving in weight; and 2. Cast alloys which are needed for engine cylinders, pistons and crankcases. Since 1914 the Laboratory has been equipped on a semi-manufacturing basis and special attention has been given to heat treatment, and full details of the development of wrought alloys are to be published shortly. Many new alloys have been rendered available for various purposes in the future, and the metals used include aluminum, copper, zinc, tin, magnesium, iron, nickle, manganese, chromium, vanadium, cobalt and beryllium; aluminum is usually the main ingredient, but alloys with magnesium as a base have also been investigated.

Among other work carried out on aluminum alloys may be mentioned the production of thin sheet to replace fabric for wing covering; a satisfactory procedure for the manufacture of sheet of the requisite thickness has been developed at the N.P.L., and methods of fixing it to the wing have been devised.

Many meteorological problems have also been investigated among them one in connection with what has been described as a "wind barrage" met with by an airship attempting to cross the sea coast landwards in the neighborhood of St. Abb's Head. This has led to valuable experiments on the effect of eddies on the motion of an airship travelling through them. Another investigation is that which seeks to give protection to kite balloons from atmospheric electrical discharges.

Dopes and fabrics have continued to receive a good deal of attention, and important investigations have been directed to reducing the rate of deterioration, with loss of gas-tightness of airship fabrics in the tropics. Considerable assistance has been rendered by the X Aircraft Depot, Aboukir, and it has been established that the deterioration is due almost entirely to the actinic radiation of sunlight, and that considerable protection can be afforded by introducing pigment into the outer layer of rubber.

The equipment of the Laboratory now includes one 3-ft., two 4-ft., three 7-ft. wind channels, and a new channel 7 ft. by 14 ft., is being installed for tests on large airplane models. In addition the R.A.E., has a 4-ft. and a 7-ft. wind channel and a second 7-ft. channel is being installed.

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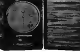


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